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Screening of Different Onion Varieties Against Onion Thrips and Evaluation of Botanical and Chemical Management Strategies in District Charsadda, Khyber Pakhtunkhwa

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ABSTRACT

Onion thrips, Thrips tabaci Lindeman, is considered one of the most injurious insect enemies of onion and can cause reduced growth, yield and marketable quality if not controlled on time. A field study was carried out at the Agriculture Research Station, Charsadda, Khyber Pakhtunkhwa province to test three onion varieties: Winner F1, Premium and Nikerson; and four management treatments: neem oil, Mexican marigold extract, moringa extract and lambda cyhalothrin; and an untreated control. The experiment was laid out in randomized complete block (RCB) design with split-plot experimental design and three replications. Three applications were sprayed and thrips population density was recorded at 3, 7 and 10 days after spray (DAS) and bulb diameter, yield and cost-benefit ratio were recorded at harvest. Lambda cyhalothrin and moringa extract had the lowest overall thrips population (9.49 and 10.95 thrips plant^{-1} respectively) while the control had the highest population (17.64 thrips plant^{-1}). Nikerson had the lowest mean number of thrips per plant (9.90 thrips plant^{-1}) among varieties and Winner F1 had the highest (17.97 thrips plant^{-1}). Premium had the highest yield (34,080 kg ha^{-1}) whereas Nikerson had the largest bulb diameter (8.72 cm). The highest mean yield (31,614 kg ha^{-1}), net benefit (Rs 460,850 ha^{-1}) and cost-

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benefit ratio (14.6) were recorded with lambda cyhalothrin. The results suggest Premium containing lambda cyhalothrin was the most productive and most economically viable, and Nikerson might be considered in situations where varietal tolerance is desired. Botanicals can be used to supplement an IPM program in the low to moderate thrips pressure range, particularly moringa extract and Mexican marigold.

Keywords: Allium Cepa; Thrips Tabaci; Botanical Extracts; Lambda Cyhalothrin; Varietal Screening; Onion Yield; Cost-Benefit Analysis

Highlights

Lambda cyhalothrin reduced the average thrips population by 46.2% compared with the untreated control.

Nikerson was the most tolerant variety based on lowest thrips density and largest bulb diameter.

Premium was the best yielding variety, producing 34,080 kg ha-1 on average across treatments.

Lambda cyhalothrin increased yield by 43.0% over control and produced the highest C:B ratio (14.6).

Moringa and Mexican marigold extracts performed better than the untreated control and may support integrated thrips management.

Introduction

Onion (Allium cepa L.) is a significant vegetable bulb crop utilized all year long as a spice, salad, vegetable and processed product. It is one of the most important Allium crops in Asia and other regions of the world where onions are cultivated for use as food and medicine. The crop is known for its rich taste, distinct aroma and nutritional value and its bulb size and quality are highly affected by cultivar, crop management practices, pest infestation and environmental conditions (Benti, 2017; Pareek et al., 2017; Greeshma et al., 2020).

Crop production and pest response are also influenced by broader agro-environmental conditions, including soil fertility, nutrient availability, organic amendments and local environmental quality. Recent studies from Khyber Pakhtunkhwa and related agro-ecological conditions have shown that biochar, phosphorus management and organic amendments can improve maize growth, nutrient uptake and soil fertility, while biochar-based approaches can also reduce heavy metal bioavailability in contaminated soils (Farooq et al., 2026; Jalal et al., 2026; A. Khan et al., 2026). Therefore, pest management studies should be interpreted within the wider context of sustainable crop production and environmental management.

Onion thrips, Thrips tabaci Lindeman (Thysanoptera: Thripidae), is a serious pest of onion due to its high reproductive capacity, polyphagous habit, ability to reproduce parthenogenetically and capacity to transmit plant pathogens. Feeding by thrips causes damage to the plant tissues, leaves to become silvery, inhibits photosynthesis and ultimately reduces bulb weight and yield. Feeding damage may also predispose plants to further disease outbreaks caused by both fungi and bacteria and can affect marketable quality (Diaz-Montano et al., 2011; Li et al., 2014; Singh et al., 2016).

Insecticides have been the main method used to control thrips in onion production

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because thrips can build up rapidly during hot and dry weather. But when used repeatedly, chemicals may lead to resistance and/or the number of natural enemies could be reduced and production costs could be higher. Resistance has been found in T. tabaci in various production systems and rotation, ETO and integration of tolerant with safer pest management tools are recommended (Adesanya et al., 2020; Wakil et al., 2023).

Similar field-based pest management work in Khyber Pakhtunkhwa has also emphasized that insect pest pressure can vary with season and location, and that effective insecticide selection may improve yield and economic return when applied at the proper stage. For example, Rehman et al. (2026) reported seasonal abundance of tomato leaf miner, Tuta absoluta, in different districts of Khyber Pakhtunkhwa and found that insecticide efficacy and cost-benefit response differed among products. This supports the need for location-specific evaluation of pest management options in vegetable crops.

Host plant resistance is an integral part of IPM. Some varieties of onion are not totally resistant, but can tolerate onion feeding damage or reduce thrips numbers. Leaf waxiness, growth habit, bulb development and varietal adaptation can affect thrips preference and recovery of the crop. Hence, screening locally grown cultivars could be useful to farmers to select cultivars that are more promising for their yield potential against pests (Ain et al., 2021; Shaikh et al., 2014; Damon et al., 2014).

Botanical extracts are also of interest as they have low life-cycle and are readily available in the area and can be used as a complementary method when pest pressure is low to moderate. Neem, moringa and marigold extracts demonstrated inconsistent results when tested for insect pest control and can be used as a component in monitoring and timely pesticide utilization programs (Khaliq et al., 2014; Tavares et al., 2021). Their effectiveness is, however, generally less than with synthetic insecticides in the event of heavy infestations and field comparison with conventional insecticides is still necessary.

The present study was hence transformed into a condensed form of research paper and the response of three onion varieties were tested for onion thrips and the efficacy of botanical extracts and lambda cyhalothrin were compared to manage thrips in agro-ecological conditions of Charsadda, Khyber Pakhtunkhwa. The specific objectives were to (i) screen onion varieties for relative susceptibility or tolerance to thrips, (ii) compare botanical extracts and lambda cyhalothrin in regard to reducing thrips population density, and (iii) evaluate the effects of various treatments on bulb diameter, yield and economic return.

Materials and Methods

Study site and experimental design

The field experiment was done at the Agriculture Research Station, Charsadda, Khyber Pakhtunkhwa, Pakistan in the onion growing season 2022-2023. The study was to compare the effectiveness of botanical extracts and a chemical insecticide in the field against onion thrips. Test cultivars were three varieties of onion, the F1 seed variety Winner, and the Premium and Nikerson varieties.

The experiment was laid out in Randomized complete block design with split-plot arrangement of the treatments and replicated thrice. The plot size was 1 m x 1 m for

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each plot. Row spacing was kept at 20 cm and plant spacing at 10 cm and all agronomic practices were provided equally for all the treatments.

The study area lies within an agro-ecological region where crop production is closely linked with water availability, soil condition and environmental quality. Previous water-quality assessments from Khyber Pakhtunkhwa reported spatial variation in physicochemical and biological drinking-water parameters, highlighting the importance of regular environmental monitoring in agricultural and peri-urban areas (S. Khan & B. Khan, 2026; A. A. Khan et al., 2025). Although the present study focused on onion thrips, such local environmental information is important for understanding the wider production context of the region.

Treatments and application rates

The management treatments evaluated were: neem oil, Mexican marigold extract, moringa extract, lambda cyhalothrin and no treatment. Spraying was done when thrips reached the economic threshold level (ETL) around 12-15 nymphs/adults per plant. The treatment details are given in Table 1.

Table 1 Treatments and application schedule used for onion thrips management.

Treatment	Rate of application	Time of application
Neem oil (Azadirachta indica)	100 g/L water	At ETL
Mexican marigold extract	100 g/L water	At ETL
Moringa extract	100 g/L water	At ETL
Lambda cyhalothrin	200 ml/ha	At ETL
Control	Water only	No insecticidal treatment

Preparation of botanical extracts

The Neem oil was bought from the local market of Khyber Pakhtunkhwa. Mexican marigold plants were dried for three days, ground with an electric blender and mixed with water before filtration through cheese cloth. The Moringa leaves were processed in the same way. The general procedure as described by Keshav and Singh (2013) was used to prepare the extracts.

The local market in Charsadda was used to purchase Lambda cyhalothrin and applied as per the experimental treatment program. Water was applied to the control plots only and no other treatment was provided for them.

Data recording

Thrips population density was recorded from five randomly selected plants from each plot. Three leaf axils per plant were observed, and the average number of thrips per plant was calculated from the selected leaves. Observations were recorded at 3, 7 and 10 days after spray (DAS) after each spray event.

At harvest, bulb diameter was measured from representative bulbs using a vernier

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caliper. Onion yield was recorded from each plot and converted into kg ha-1. Economic analysis was performed by calculating gross income, treatment cost, return over control, net benefit and cost-benefit ratio using the market price and input costs recorded in the original experiment.

Statistical and graphical analysis

The recorded data were analyzed through analysis of variance (ANOVA), and treatment means were separated using the least significant difference (LSD) test at $P < 0.05$. The original thesis analyzed the data in Statistix 8.1. For the present research-paper version, Python was used only to prepare clear publication-style graphs from the approved mean tables; no original numerical values were changed.

Results

Effect of treatments on thrips population

Thrips population density differed clearly among treatments after all spray events. Across the three spray dates, lambda cyhalothrin recorded the lowest average thrips population (9.49 thrips plant^{-1}), followed by moringa extract (10.95 thrips plant^{-1}) and Mexican marigold (12.09 thrips plant^{-1}). The untreated control maintained the highest average population (17.64 thrips plant^{-1}). Compared with the control, lambda cyhalothrin reduced mean thrips population by 46.2%, moringa extract by 37.9%, Mexican marigold by 31.5% and neem oil by 15.0%.

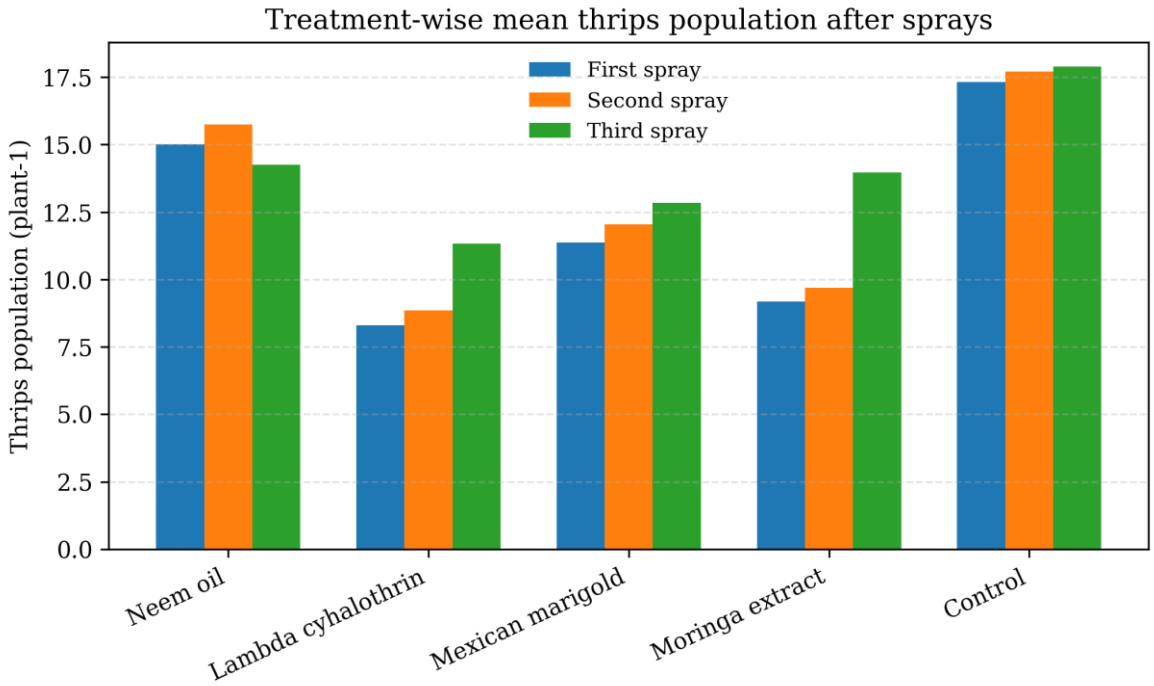

Figure 1 Treatment-wise mean thrips population after first, second and third sprays.

The first spray showed the strongest early reduction under lambda cyhalothrin, where the treatment mean was 8.30 thrips plant^{-1} compared with 17.33 thrips plant^{-1} in the control. A similar pattern occurred after the second spray, with lambda cyhalothrin

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maintaining the lowest treatment mean (8.85 thrips plant-1) and the control showing the highest mean (17.70 thrips plant^{-1}). After the third spray, thrips pressure increased in all treatments, but lambda cyhalothrin still produced the lowest treatment mean (11.33 thrips plant^{-1}), while the control remained highest (17.89 thrips plant^{-1}).

Varietal response to onion thrips

The three onion varieties differed in their response to thrips infestation. Winner F1 recorded the highest overall thrips population (17.97 thrips plant-1), indicating greater susceptibility. Nikerson recorded the lowest overall thrips population (9.9 thrips plant-1), suggesting better tolerance or lower attractiveness to thrips. Premium showed an intermediate response (11.25 thrips plant-1) but maintained higher yield at harvest.

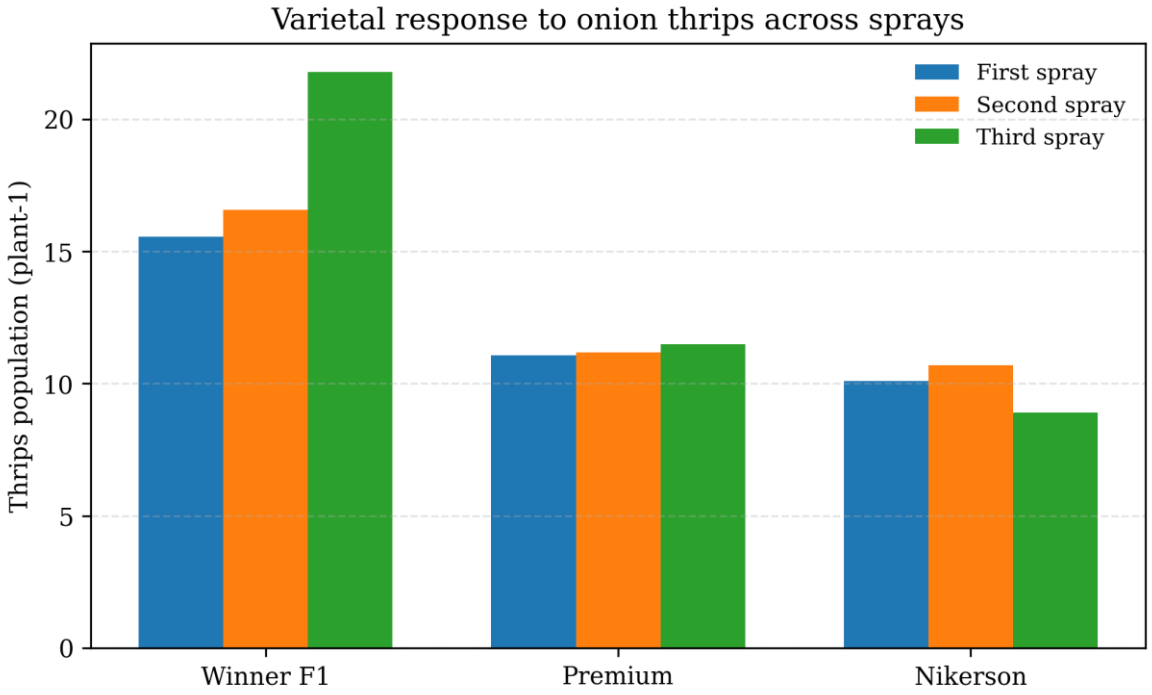

Figure 2 Varietal response to onion thrips after first, second and third sprays.

The varietal pattern became more distinct at the third spray stage, where Winner F1 recorded 21.78 thrips plant-1, Premium recorded 11.49 thrips plant-1 and Nikerson recorded only 8.91 thrips plant-1. These results show that varietal selection can play an important role in reducing thrips pressure and should not be ignored when planning thrips management.

Post-spray population trend

The days-after-spray trend showed that thrips populations were generally lower at 3 DAS and increased by 7 or 10 DAS. During the first and second sprays, the highest population was recorded at 10 DAS, while after the third spray the highest mean was recorded at 7 DAS and then declined slightly at 10 DAS. This pattern indicates that monitoring must continue after spraying, because thrips populations can recover within one week under favorable conditions.

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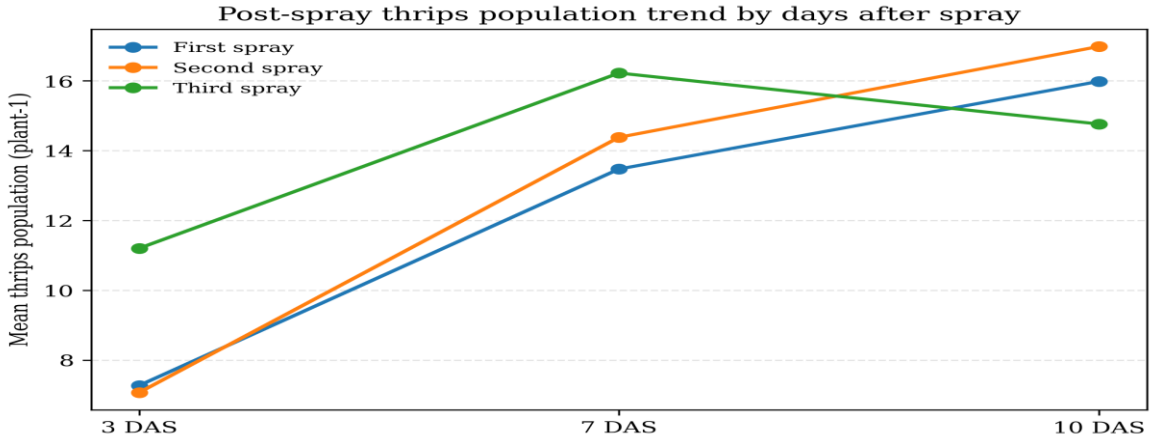

Figure 3 Post-spray trend of mean thrips population at 3, 7 and 10 days after spray.

Bulb diameter response

Bulb diameter was significantly influenced by both treatment and variety. Lambda cyhalothrin produced the highest mean bulb diameter (8.89 cm), followed by Mexican marigold (7.84 cm), neem oil (7.70 cm), moringa extract (7.34 cm) and control (6.70 cm). Among varieties, Nikerson produced the largest mean bulb diameter (8.72 cm), followed by Premium (8.28 cm) and Winner F1 (6.08 cm). The maximum bulb diameter was observed in Nikerson treated with lambda cyhalothrin (9.42 cm), while the minimum was recorded in Winner F1 under control conditions (4.36 cm).

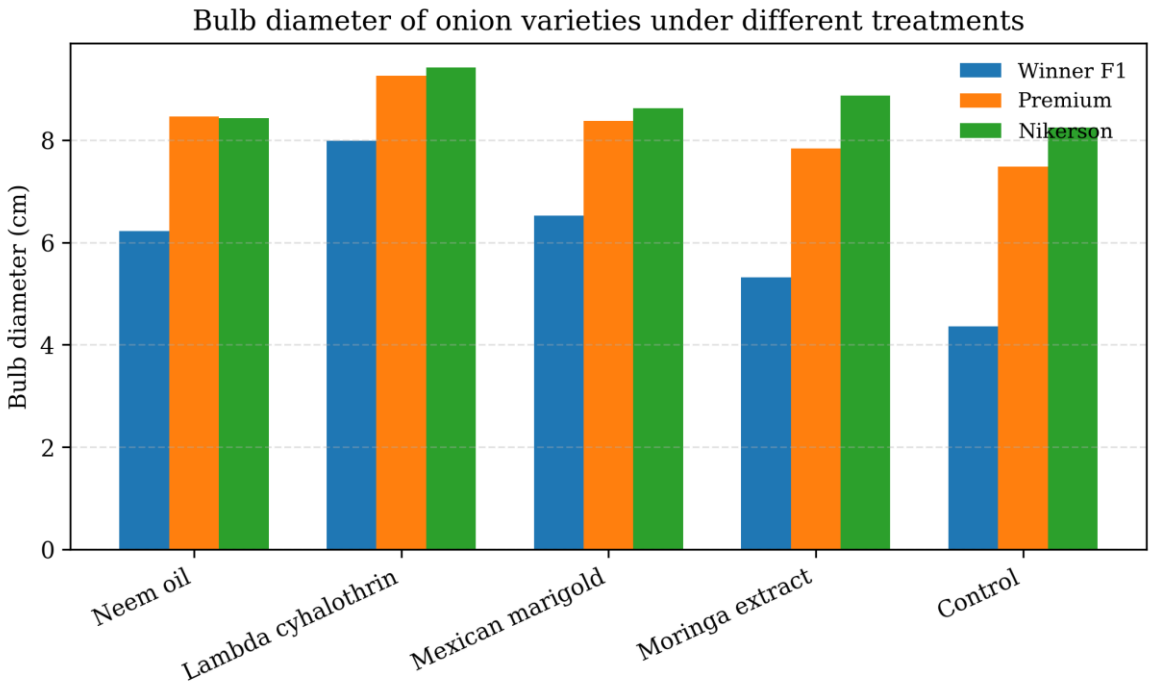

Figure 4 Bulb diameter of onion varieties as affected by botanical and chemical treatments.

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Onion yield response

Yield response followed the general pattern of thrips suppression, but varietal yield potential also contributed strongly. Lambda cyhalothrin recorded the highest mean yield (31,614 kg ha^{-1}), followed by Mexican marigold (28,335 kg ha^{-1}), moringa extract (24,835 kg ha^{-1}), neem oil (23,746 kg ha^{-1}) and control (22,106 kg ha^{-1}). Premium gave the highest varietal mean yield (34,080 kg ha^{-1}), followed by Nikerson (28,350 kg ha^{-1}) and Winner F1 (15,952 kg ha^{-1}).

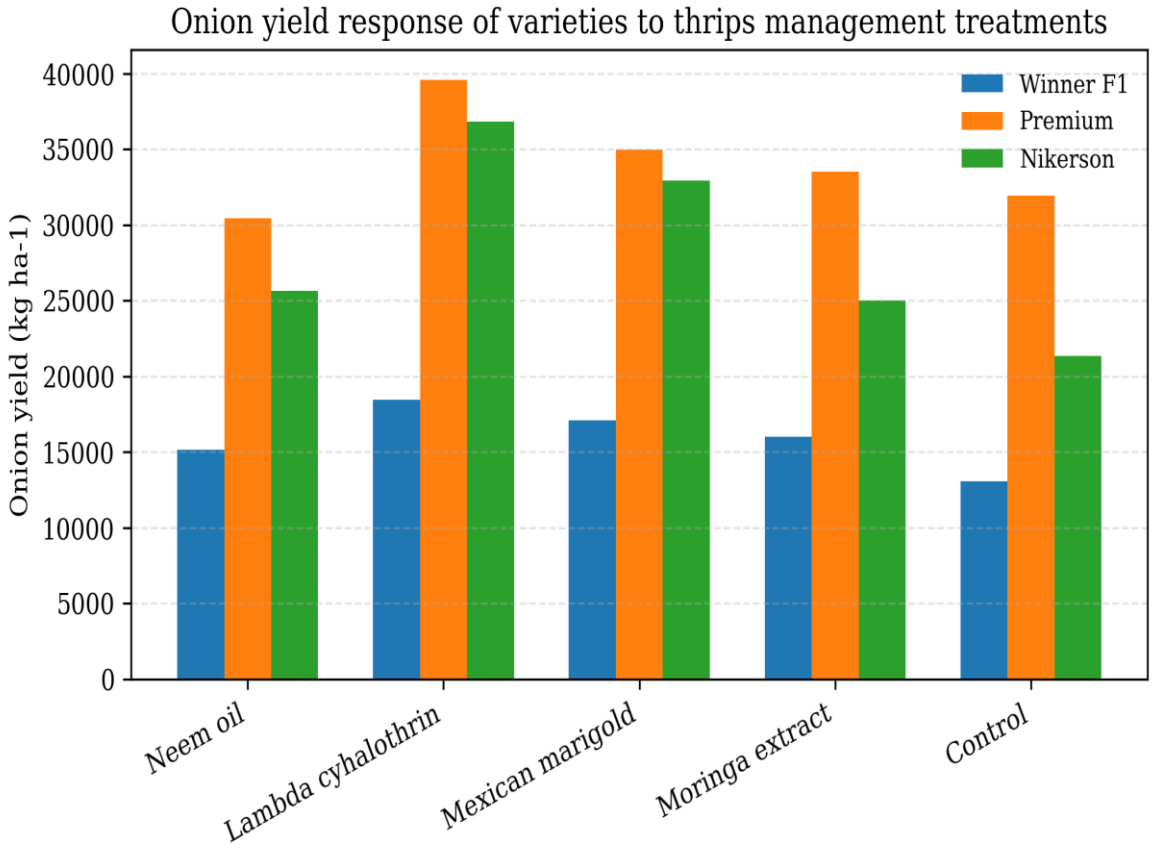

Figure 5 Onion yield response of three varieties to thrips management treatments.

The most effective treatment-variety combination was Premium (with lambda cyhalothrin, 39,570 kg ha-1) followed by Nikerson (with lambda cyhalothrin, 36,840 kg ha-1). The lowest yield was obtained with Winner F1 under control conditions (13,063 kg ha-1). This demonstrates that the highest yielding variety and good thrips control gave the best agronomic performance.

Economic analysis

The economic analysis revealed that lambda cyhalothrin was the most economical option with a net economic benefit of Rs 460,850 ha^{-1} and a cost-benefit ratio of 14.6. Mexican marigold was the second most effective treatment with a net benefit of Rs 301,600 ha^{-1} and a cost-benefit ratio of 11.2. The highest net benefit was obtained with moringa extract (Rs 127,950 ha^{-1}) and the lowest net benefit was observed in the neem oil treated plots (Rs 72,000 ha^{-1}).

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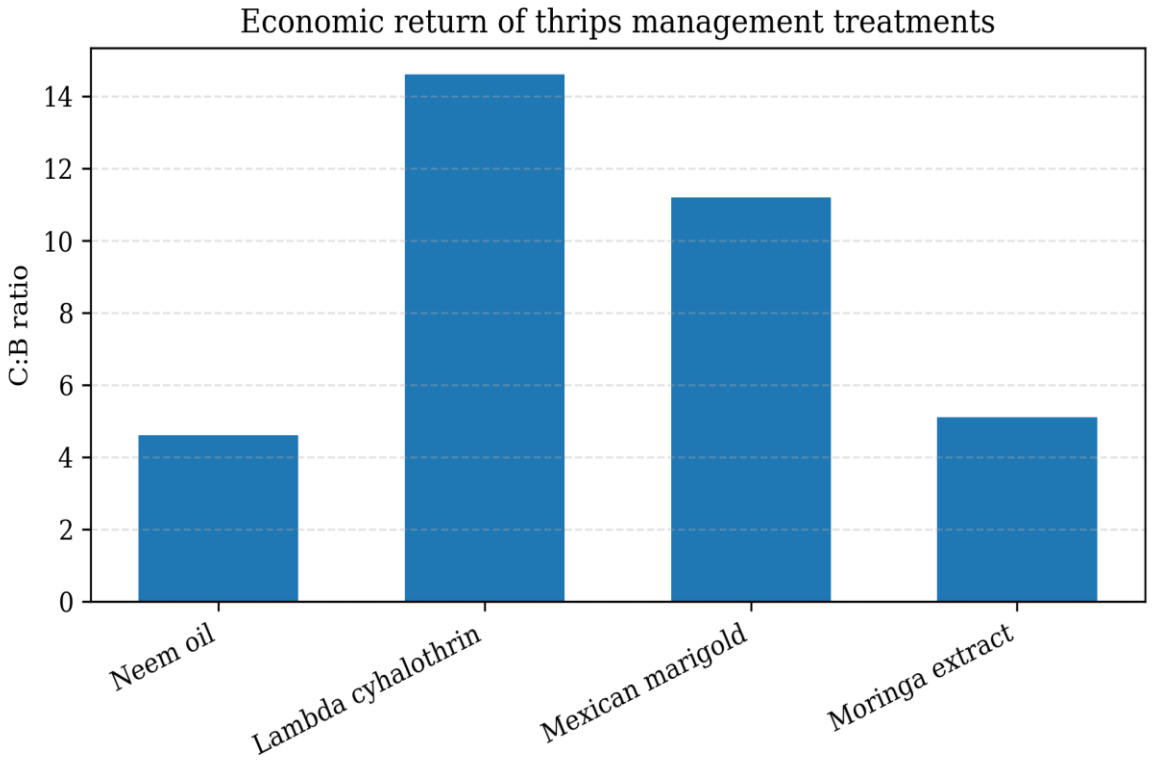

Figure 6 Cost-benefit ratio of thrips management treatments compared with untreated control.

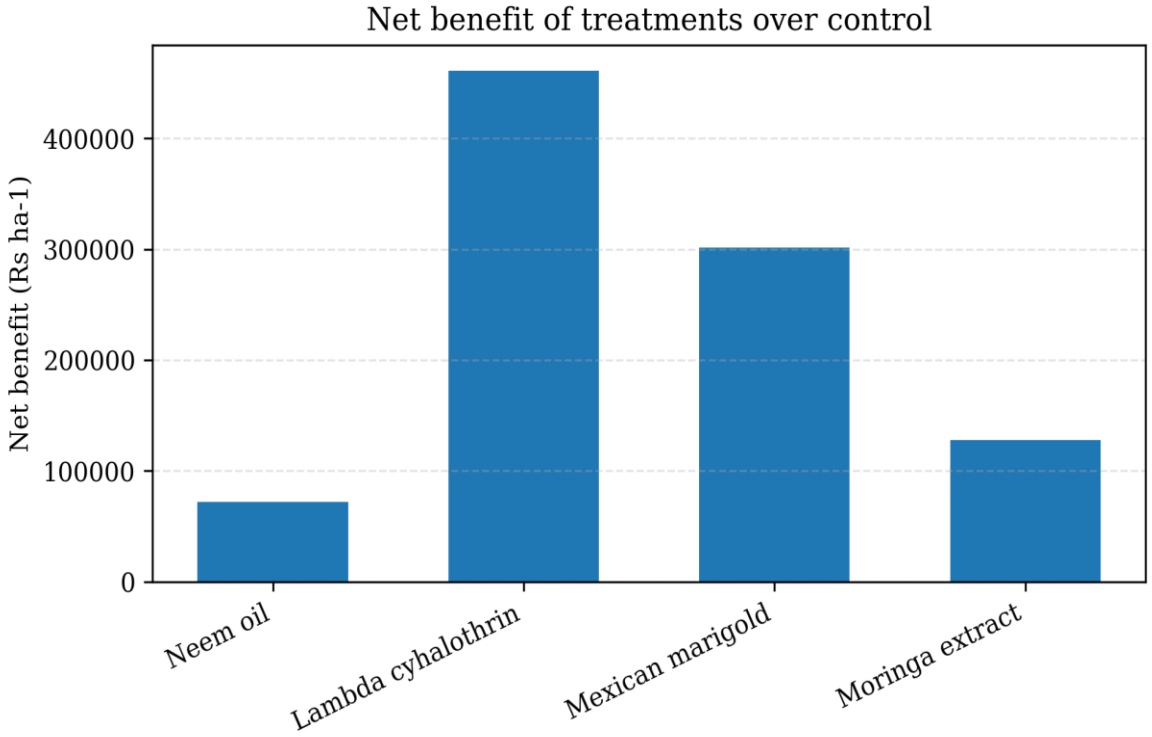

Figure 7 Net benefit of thrips management treatments over untreated control.

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Summary of treatment and varietal performance

Table 2 Overall treatment performance for thrips suppression, onion yield and economic return.

Treatment	1st spray thrips	2nd spray thrips	3rd spray thrips	Overall thrips	Mean yield (kg ha-1)	C:B ratio
Neem oil	15.00	15.74	14.26	15.00	23,746	4.6
Lambda cyhalothrin	8.30	8.85	11.33	9.49	31,614	14.6
Mexican marigold	11.37	12.04	12.85	12.09	28,335	11.2
Moringa extract	9.19	9.70	13.96	10.95	24,835	5.1
Control	17.33	17.70	17.89	17.64	22,106	-

Table 3 Overall varietal response to thrips infestation, bulb diameter and yield.

Variety	1st spray thrips	2nd spray thrips	3rd spray thrips	Overall thrips	Bulb diameter (cm)	Yield (kg ha-1)
Winner F1	15.56	16.56	21.78	17.97	6.08	15,952
Premium	11.07	11.18	11.49	11.25	8.28	34,080
Nikerson	10.09	10.69	8.91	9.90	8.72	28,350

Discussion

The results verified that onion thrips can be significantly reduced by appropriate management, but the effectiveness of the treatments differs significantly among the botanical extracts and synthetic insecticide. In all three spray events, the lowest amount of thrips emerged with lambda cyhalothrin. This response could be related to the fast contact and ingestion rate of pyrethroid insecticides and may be effective in reducing the mobile thrips stages if applied at the right time. However, the efficacy of lambda cyhalothrin or other chemical insecticides against T. tabaci has been reported by similar efficiencies by Shelton et al. (2003), Ullah et al. (2010) and Shweta et al. (2019).

The stronger response of lambda cyhalothrin in the present study is also consistent with the general pattern observed in other vegetable pest management studies, where properly selected synthetic insecticides produced higher pest reduction, marketable yield and economic return under field conditions (Rehman et al., 2026). However, chemical control should be used carefully and only when pest pressure reaches the economic threshold level, because repeated use of a single active ingredient can increase the risk of resistance development.

Favourable field conditions result in the buildup of thrips populations at later observation times which indicates that a single spray is not sufficient to give long-term suppression. Thrips may survive in the leaf axils of onions where spray deposition is not as high. They can also have a short generation time and high

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reproductive potential, which can result in quick population recovery. This trend, along with the use of ETL spray decisions, further underscores the necessity of frequent post-spray scouting, and the fact that calendar spraying is not recommended (Nault and Shelton, 2010; Wakil et al., 2023).

Moderate performance was observed with the botanical extracts. Moringa extract and Mexican marigold were more effective at reducing thrips population than neem oil in the overall treatment comparison and both treatments were superior to the untreated control in terms of bulb diameter and yield. The variable effect of botanicals is consistent with previous results with plant extracts that can reduce thrips population but may not be as consistent as synthetic insecticides when pressure is high (Khaliq et al., 2014; Pandey et al., 2013; Tavares et al., 2021). Botanicals, therefore, might be more appropriate in the context of integrated management, particularly when farmers seek to decrease reliance on chemicals.

There were also differences between the varieties. Winner F1 had the highest thrips infestation and the lowest mean yield and bulb size. The bulbs from Nikerson had the lowest thrips population and the biggest bulbs, which mean that he was more tolerant or less attractive to thrips. Onion varieties have been reported to have different responses to thrips, possibly due to differences in leaf waxiness, growth characteristics, plant architecture, and tolerance to feeding injury (Damon et al., 2014; Shaikh et al., 2014; Ain et al., 2021).

Premium yielded the highest bulb numbers with all treatments, but Nikerson had the highest tolerance and bulb size. This means that tolerance to thrips and end yield are not necessarily synonymous. The seed yield potential for premium may have been higher than it was at the Charsadda site, whereas the Nikerson may have been helpful in high thrips pressure and can be grown in a reduced susceptibility environment. Varietal differences in onion growth and yield have been cited as a result of genotype, adaptation, plant spacing, and management and environmental conditions (Alemu et al., 2022; Kiani and Mashayekhi, 2023).

The yield response observed in this study may also be linked with the general role of crop nutrition and soil health in supporting plant growth under stress. Farooq et al. (2026) found that phosphorus applied with biochar improved maize yield and phosphorus-use efficiency, while Jalal et al. (2026) and A. Khan et al. (2026) reported that biochar-based amendments improved maize growth and reduced heavy-metal stress in contaminated soil. These findings support the concept that pest management should be combined with improved soil and nutrient management for better crop productivity.

The economic analysis confirmed the agronomic results. The most expensive treatment was also the most productive, the most return over control treatment, the most net benefit and the most cost-benefit ratio was lambda cyhalothrin. This translates into treatment cost being offset in the event of a treatment being economically important because of thrips. Mexican marigold exhibited also a good economic return and could be used in regions where farmers prefer non-synthetic alternatives. Under the tested conditions, neem oil showed the least net return suggesting that the rate, formulation or field efficiency of this oil might be further optimized.

In terms of integrated pest management, the best advice is to not use only one

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chemical product. The use of the same active ingredient more than once could lead to the emergence of resistance in T. tabaci. Hence, the use of lambda cyhalothrin should be considered only at ETL levels and only when combined with other compatible methods such as tolerant varieties, botanicals, field sanitation, irrigation management and conservation of natural enemies (Adesanya et al., 2020; Wakil et al., 2023).

Conclusion

The present study revealed that thrips population, bulb diameter, yield and economics were significantly affected by management treatment as well as onion variety in Charsadda, KPK. Onion thrips were best suppressed with lambda cyhalothrin and the highest yields, net benefit and cost-benefit ratio were achieved. In the comparison of the different botanicals, Mexican marigold extract was superior to the untreated control and may be utilized as an adjunct management strategy for thrips. The lowest thrips population and largest bulb diameter led to the highest overall tolerance with Nikerson, while Premium showed the highest yield and best performance when combined with lambda cyhalothrin. Premium variety and timely lambda cyhalothrin application at ETL provided the highest productivity and profitability, while Nikerson and botanical extracts are valuable for reducing the reliance on chemicals in integrated pest management systems.

Recommendations

Farmers in Charsadda and similar agro-ecological areas should use the Premium variety with timely lambda cyhalothrin application at ETL to achieve higher onion yield, while Nikerson may be preferred in fields with repeated thrips problems due to its lower thrips population and larger bulb diameter.

Spray decisions should be based on regular scouting rather than fixed calendar spraying. Moringa and Mexican marigold extracts may be used as safer supplementary options under low to moderate infestation, while repeated use of lambda cyhalothrin alone should be avoided to reduce resistance risk.

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